Dynamic Stability of SMIB System with Fuzzy Logic Based Power System Stabilizer

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Article Info

Article history:

Received Nov 12th, 2014
Accepted Nov 18th, 2014
Publication Nov 22th , 2014

Keyword:

power system stabilizers,
fuzzy logic controller,
membership functions

ABSTRACT

This paper studies Dynamic Analysis and Stability of Single machine connected to infinite bus (SMIB) with power system stabilizer (PSS) in presence of Fuzzy logic controller (FLC). Here PSS is modeled using fuzzy logic controller and the response is compared with the responses of the system in presence of conventional PI, PID controllers. In case of FLC, different membership functions are studied and all responses are compared. Finally the fuzzy logic based PSS with Gauss and triangular membership functions give better performance. Matlab-Simulink is used to test the results.

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I. INTRODUCTION

The electrical energy has become the main form of energy for any of consumption in these days. There is always a need of making electric energy generation and transmission, both more economic and reliable. The voltages throughout the system are also controlled to be within ±5% of their specified values by automatic voltage regulators acting on the generator field exciters, and by the sources of reactive power in the network. For appropriate working, this large integrated system requires a stable operating condition. The power system is a lively system. It is frequently subjected to small disorders, due to which the generators relative angles changes. For the interconnected system to be able to provide the load power demand when the transients caused by disturbance die out, a new acceptable steady state operating condition is attained. That is, the power system has to be stable. It is important that these disturbances do not drive the system to an unstable situation. [1].

Stability in power systems is generally referred to as the ability of generating units to maintain synchronous operation. It is useful to classify the modes of instability of power systems. In general stability into the following types: Transient stability which is the ability to maintain synchronism when the system is subjected to a large disturbance. In the resulting system response, the changes in the dynamic variables are large and the nonlinear behavior of the system is important.

Small Signal Stability which is the ability of the system to maintain stability under small disturbance. Such disturbances occur continuously in the normal operation of a power system due to small variations in load and generation. The first is the oscillations linked with a single generator or a single plant that is called “local modes” or “plant modes”. Local modes in General have frequencies in the range of 0.7 to 2 Hz. The characteristics of these oscillations are well understood. They may be studied adequately, and satisfactory solutions to stability problems are developed from a system,

which has detailed representation only in the vicinity of the plant [3] - [10]. The second is the oscillations associated with groups of generators, or groups of plants. They are called “inter-area modes”. Inter-area modes have frequencies in the range of 0.1 to 0.8 Hz. The characteristics of these modes of oscillation, and the factors affecting them, are not fully understood. They are more complex to study, and to control. A detailed representation of the entire interconnected system requires studying inter-area modes [2], [5].

II. Power System Modeling

Modeling is the method of developing mathematical equations for the system parameters. The basic modeling is the classical model for the generator. To this basic model the effect of synchronous machine field circuit dynamics and excitation system is added to frame the complete system block diagram when it is taken as single machine infinite bus system as shown in Fig.1 below.

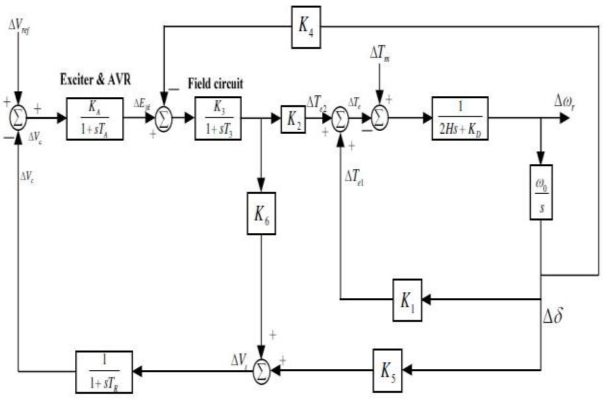

Fig.1 SMIB System

III. Power System Stabilizers

The basic function of a power system stabilizer is to modulate generator excitation to provide damping to the system oscillations of concern. These oscillations are typically in the frequency range of 0.2to 2.0Hz, and insufficient damping of these oscillations may limit the ability to transmit power.

To provide damping, the PSS must produce a component of electrical torque which is in phase with the rotor speed deviation. The implementation details differ, depending on the stabilizer input signal employed. However, for any input signal the PSS transfer function must compensate for the phase lag of the combined generator, excitation system, and power system. They collectively determine the transfer function between the PSS output and the electrical torque component which can be modulated via excitation system. [13], [14].

A. *Structure of Conventional Power System Stabilizers:*

The conventional lead–lag structure is chosen in this study as a Conventional PSS (CPSS). The structure of the CPSS controller model is shown in Fig below.

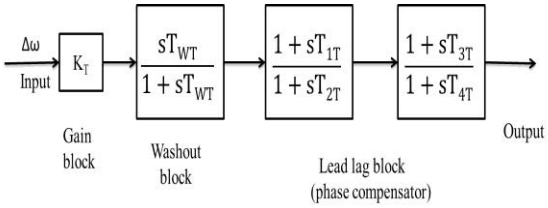

Fig.2 Conventional Power System Stabilizer Block Diagram

It consists of a gain block, signal wash out block and a two stage lead-lag phase compensation blocks. It consists of a gain block with gain K_T, a signal washout block and two-stage phase compensation block as shown in figure. The phase compensation block provides the appropriate phase-lead characteristics to compensate for the phase lag between input and the output signals. The signal washout block serves as a high-pass filter, with the time constant T_W high enough to allow signals associated with oscillations in input signal to pass unchanged.

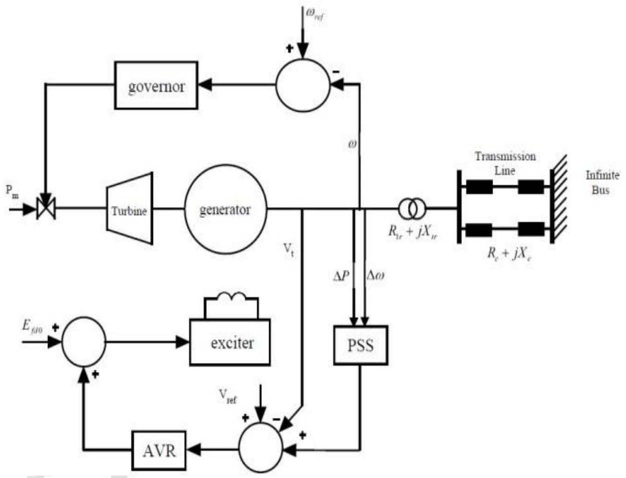

Fig.3 Power System Configuration

The signal washout block serves as high pass filter, with time constant *Tw* high enough to allow signals associated with oscillations in ωr to pass unchanged, which removes d.c signals. Without it, steady changes in speed would modify the terminal voltage. It allows PSS to respond only to changes in speed. The stabilizer gain K_{STAB} determines the amount of damping introduced by PSS. Ideally, the gain should be set at a value corresponding to maximum damping; however, it is limited by other consideration. The block diagram of a single machine infinite bus (SMIB) system, which illustrates the position of a PSS, is shown in above Figure. The system consists of a generating unit connected to an infinite bus through a transformer and a pair of transmission lines. An excitation system and automatic

voltage regulator (AVR) are used to control the terminal voltage of the generator. An associated governor monitors the shaft frequency and controls mechanical power.

Adding a PSS to the block diagram shown in Figure 1, the block diagram of the power system with PSS is obtained as shown in Figure. Since the Purpose of a PSS is to introduce a damping torque component, a logical signal to use as the input of PSS is $\Delta\omega_r$. If the exciter transfer function and the generator transfer function between ΔE_{fd} and ΔT_e were pure gains, a direct feedback of $\Delta\omega_r$ would result in a damping torque component. However, both transfer functions between ΔE_{fd} and ΔT_e exhibit frequency dependent gain and phase characteristics. Therefore, the CPSS transfer function should have an appropriate phase compensation circuit to compensate for the phase lag between the exciter input and the electrical torque. In the ideal case, with the phase characteristics of $Gpss(s)$ being an exact inverse of the exciter and generator phase characteristics, the CPSS would result in a pure damping torque at all oscillating frequencies.

IV. Fuzzy Pss

Fuzzy logic controllers are very useful when an exact mathematical model of the plant is not available; however, experienced human operators are available for providing qualitative rules to control the system. Fuzzy logic, which is the logic on which fuzzy logic control is based, is much closer in spirit to human thinking and natural language than the traditional logic systems. Basically, it provides an effective mean of capturing the approximate, inexact nature of our knowledge about the real world. Viewed in this perspective, the essential part of the fuzzy logic controller (FLC) is a set of linguistic control rules related by dual concepts of fuzzy implication and the compositional rule of inference [15], [16]. A triangular membership function is used here; they are shown in table 1:

Table.1 Membership Functions for fuzzy variables

NB	Negative Big
NM	Negative Medium
NS	Negative Small
ZE	Zero
PS	Positive Small
PM	Positive Medium
PB	Positive Big

The rules for the required fuzzy logic controller to get the desired performance can be shown in following table 2.

Table.2 Decision Table

acceleration / Speed deviation	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NS	ZE	ZE	PS
NM	NB	NB	NM	NS	ZE	PS	PM
NS	NB	NB	NM	ZE	PS	PM	PB
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NB	NM	NS	ZE	PM	PB	PB
PM	NM	NS	ZE	PS	PM	PB	PB
PB	NS	ZE	ZE	PS	PB	PB	PB

The De-fuzzification technique use here is centroid method, Centroid method is also known as center of gravity method, it obtains the center of area z^* occupied by the fuzzy set A of universe of discourse Z. It is given by the expression

$$z^* = \frac{\int_z \mu_A(z) z dz}{\int_z \mu_A(z) dz}$$

for continuous membership function,

And,

$$z^* = \frac{\sum_{i=1}^{n} z_i \mu(z_i)}{\sum_{i=1}^{n} \mu(z_i)}$$

Here μA (z) is the aggregated output MF. This is the most widely used adopted Defuzzification strategy, which is reminiscent of the calculation of expected values of probability distributions. The system with Fuzzy Logic based PSS is

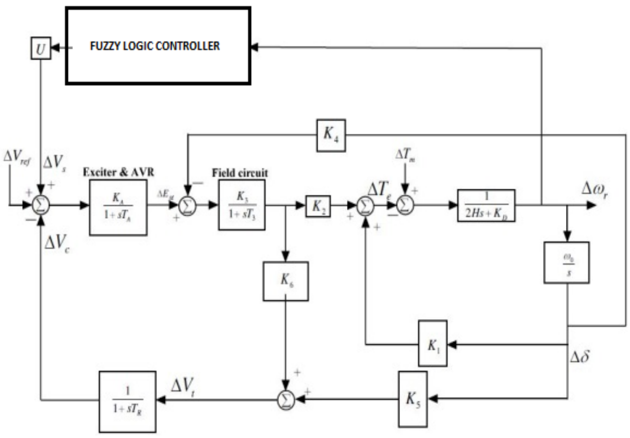

Fig.4 The System with Fuzzy Logic Based PSS

V. Results

The response of the system which is SMIB system without using Power System Stabilizers is shown in figure 5. Response of the system using PID controller based PSS is

shown in figure 6. The required response of the system using Fuzzy logic controller based PSS is shown in figure 7. By obsorving the following results tha oscillations are in the respose of the system with fuzzy logic controller based power system stabilizer is much less when compared it to the PID controller based power system stabilizer, but without using any controller or power system stabilizer the system stability will be occure in after many oscillations and takes much time. By applying fuzzy logic based power system stabilizer the dynamic stability of single machine infinite bus system will be get stability in short time

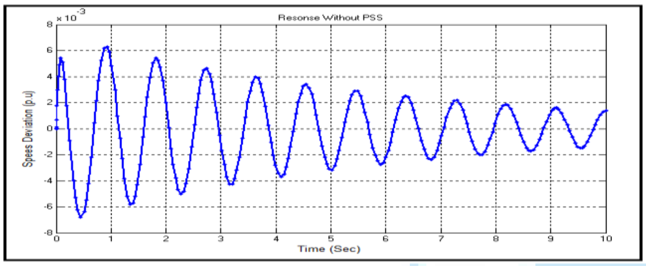

Fig.5 Response of the system without PSS

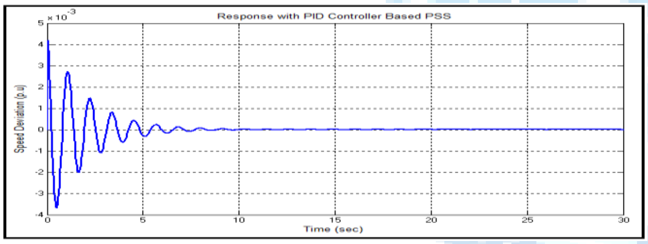

Fig.6 Response with PID controller based PSS

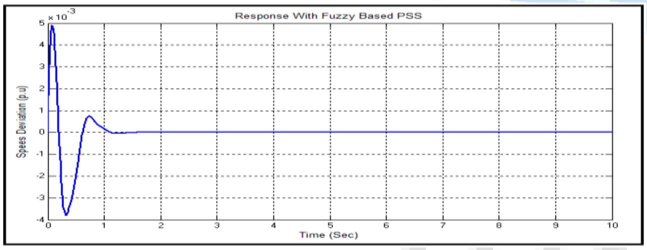

Fig.7 Response of the system with Fuzzy Logic based PSS

By using various membership functions for the fuzzy logic controller which is used to design the PSS the individual responses obtained are shown in below figures. For Generally Bell Shaped membership function, the response can be obtained is

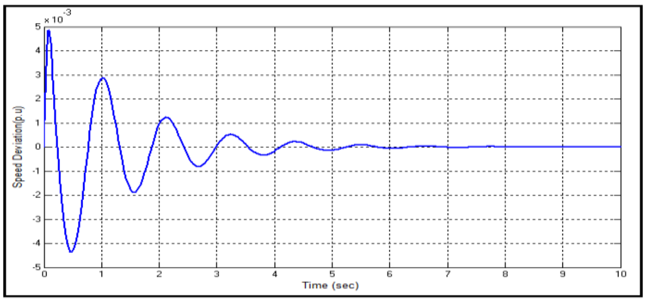

Fig.8 Response of the system with general bell shaped membership function

For Gaussian membership function, the response can be obatined as,

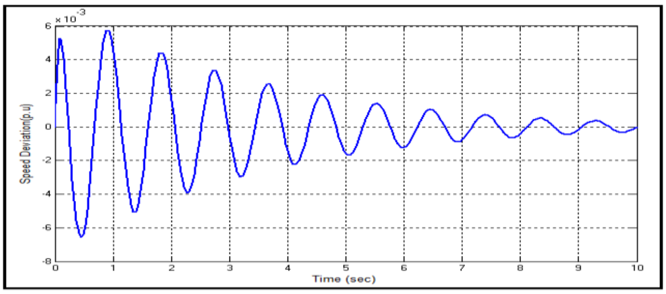

Fig.9 Response of the system with gaussian membership function

For pi shaped membership function, the response can be obtained as,

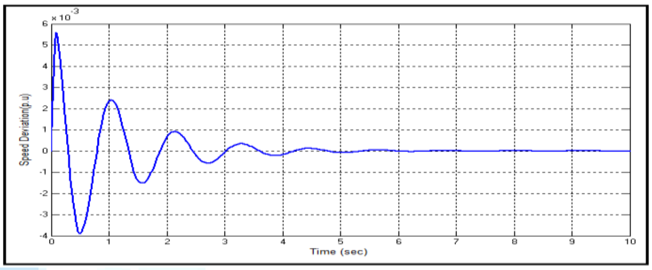

Fig.10 Response of the system with pi shapped membership function

The response of the system with various membership functions for the fuzzy logic based PSS used in the SMIB system is shown in Fig.11.

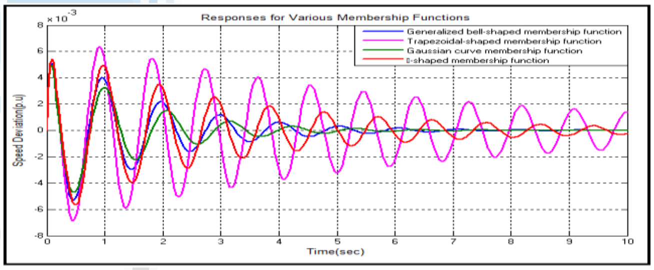

Fig.11 Response for different membership functions

For the comparison the response of the system without any controller, with PID based and Fuzzy Logic based Power system can be obtained as shown in Fig.12.

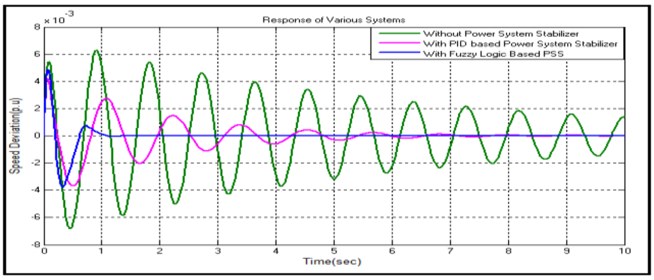

Fig.12 Response for different system configurations

VI. Comparisons

The following tables are the comparisons of SMIB system with different controllers.

Table.3 Comparison between various system

Type of system	Rise Time (sec)	Settling Time (sec)	Peak Time (sec)	Oscillations
Without using PSS	0.029	37	0.084	Comparatively More
With PID based PSS	0.025	12.3	0.064	Comparatively medium
With Fuzzy tuned PSS	0.026	1.46	0.07	Less

And by considering the various membership functions for the fuzzy logic controller used in the PSS is shown in Table.4

Table.4 Comparison between different membership function responses

Type of membership function	Settling Time (sec)	Peak Time (sec)	Rise Time (sec)	Oscillations
Bell shaped	10.7	0.089	0.03	Comparatively low
Trapezoidal	37.8	0.084	0.02	Comparatively more
Gauss	9.0	0.089	0.03	Comparatively low
Pi Shaped	20.4	0.085	0.03	Comparatively medium

VII. Conclusion

This paper presented a method for the design of fuzzy logic power system stabilizers (FLPSS) in a single machine connected to an infinite bus system (SMIB). The power system stabilizer used here is tuned with various controllers like PID, Fuzzy logic based models and is tested in a SMIB system and the dynamic stability of the system responses is obtained.. From the above comparisons the Fuzzy logic based power system stabilizer gives the better response when compared it to the PID controller tuned Power system stabilizer on the single machine connected to infinite bus system.

Appendix

The Parameters of the synchronous machine, excitation system and conventional PSS are as follows.

[a] Synchronous machine constants:

x_d= 2.64 pu, x'_d= 0.28 pu

x_q= 1.32 pu, x_q= 0.29 pu

R_E= 0.004 pu, X_E= 0.73 pu

f= 60 Hz, H= 4.5 sec

[b] Excitation system constants:

K_A= 100, T_A= 0.05, T_R= 0.015

E_{FMAX}= 5.0, E_{FMIN}= -5.0

[c] PSS constants: K_{STAB}= 20, T_w= 1.4 sec

T_1= 0.154 sec, T_2= 0.033 sec

V_{SMAX}= 0.2, V_{SMIN}= -0.2.

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